Optical Communications – an emerging technology at NASA

National Aeronautics and Space Administration

Jet Propulsion Laboratory
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Abstract

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Optical communications has been pursued since the invention of lasers in the early 1960's. Recent demands on bandwidth for disseminating information worldwide has spurred this field, with advances extending beyond terrestrial applications to airborne and satellite communications. In the past decade space-to-ground and space-to-space demonstrations from geostationary (GEO) and low-earth orbiting (LEO) satellites were carried out by ESA and JAXA. In this decade NASA carried out a successful bi-directional demonstration of optical communication from a lunar orbiting spacecraft called the Lunar Atmospheric Dust Environment Explorer (LADEE). This was followed by a LEO-to-Ground demonstration from the International Space Station called Optical Payload for Lasercom Science (OPALS). In the wake of these successful demonstrations, NASA is planning advanced demonstrations in the next decade. The Laser Communication Relay Demonstration (LCRD) to cover Earth, geostationary and eventually LEO nodes, is planned. The Deep Space Optical Communications (DSOC) Project is planning to demonstrate the first optical communication link from astronomical unit (AU) distances. The current plan is to host the space flight transceiver on the Psyche Mission spacecraft to be launched in the early part of the next decade. DSOC is motivated by information capacity demands from higher resolution science instruments and future human exploration of planetary destinations, such as, Mars and beyond. NASA is also planning the Optical to Orion (O2O) demonstration on the first crewed EM-2 mission. In this talk a brief summary of the highlights of the past demonstrations will be presented. A discussion of the advances being pursued by the LCRD and DSOC demonstrations will be summarized emphasizing the "first time" technologies planned. Further key developments needed for maturing into an operational service capability for satisfying NASA's longer term science and exploration goals will also be mentioned.

- **Graphical summary of possible optical communications (lasercom) links**

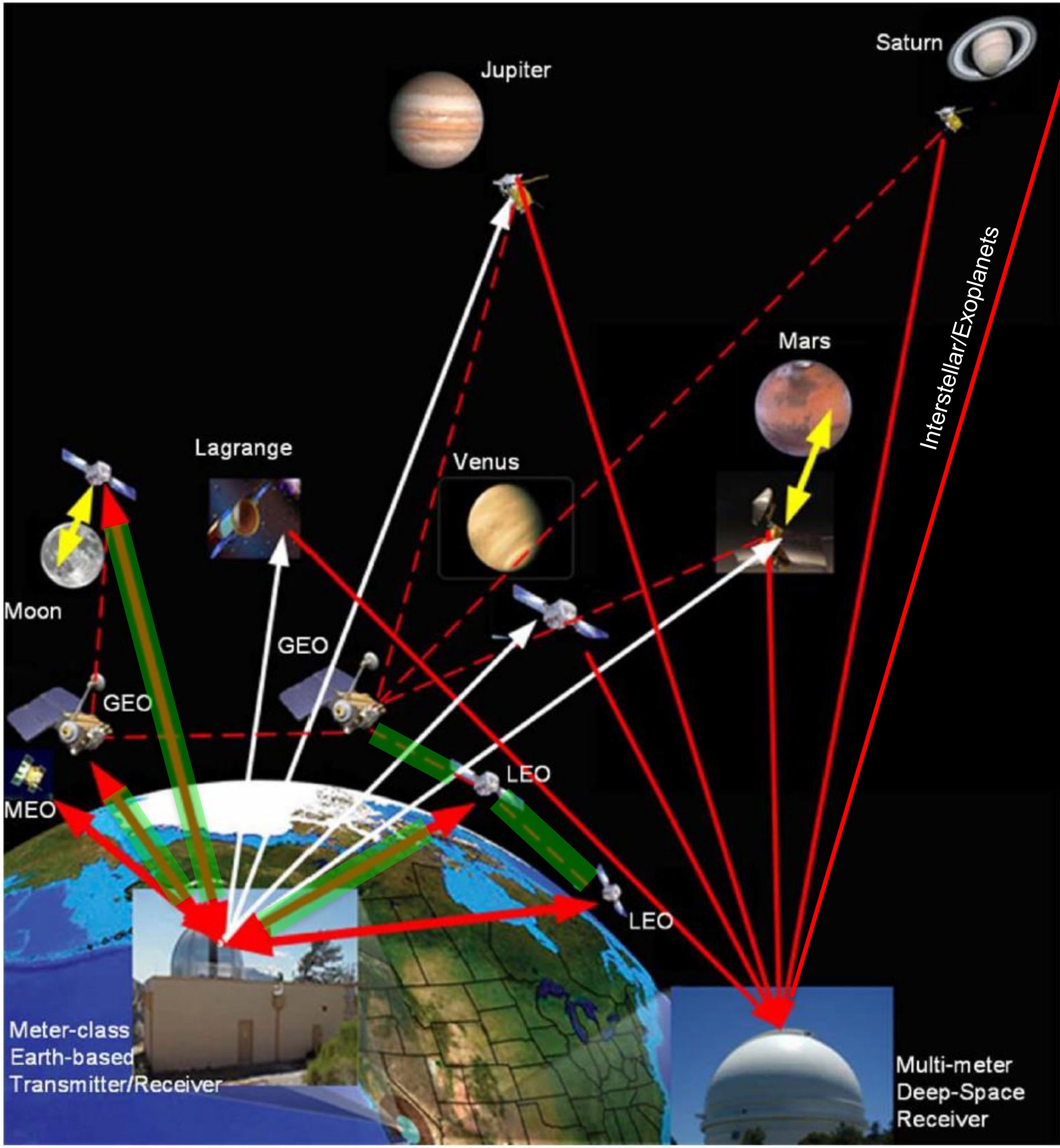
Near-Earth bi-directional *(LEO, MEO, GEO, Moon*

Orbiter-to-lander or rover *(Moon, Mars, other bodies)*

Inter-satellite *(Moon, Mars, other bodies)*

Downlink from deep-space *(Mars, Venus, Jupiter Saturn*

Uplink to deep-space



Laser Communications Systems

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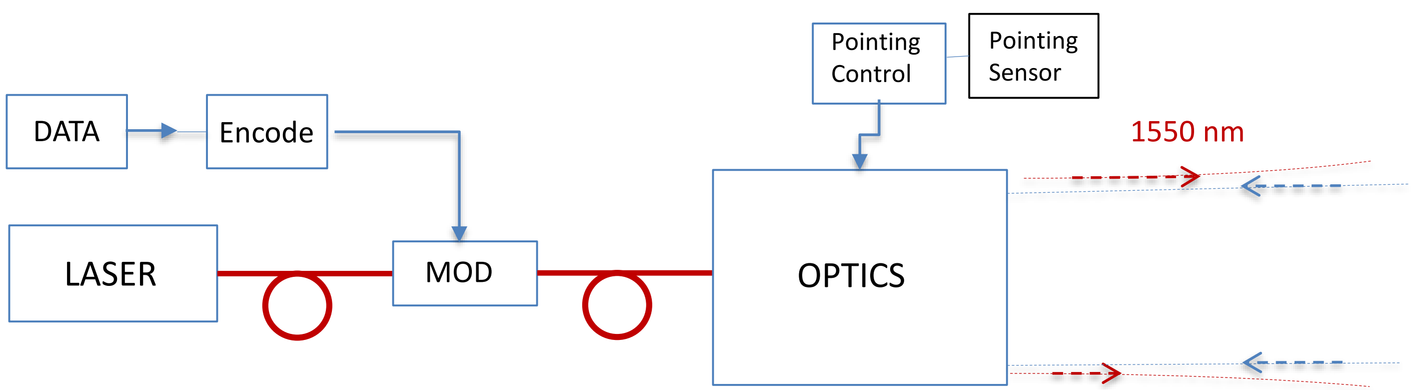
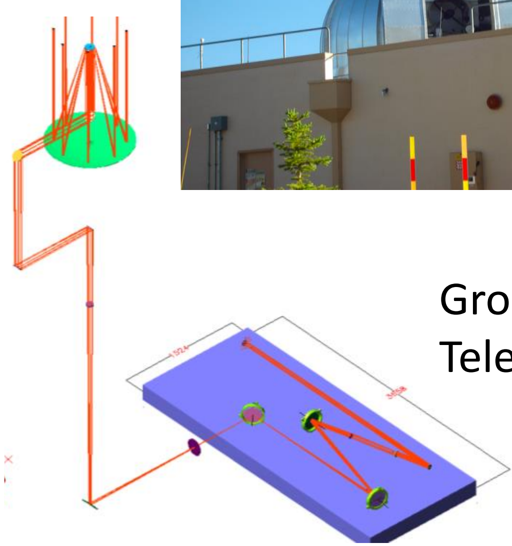
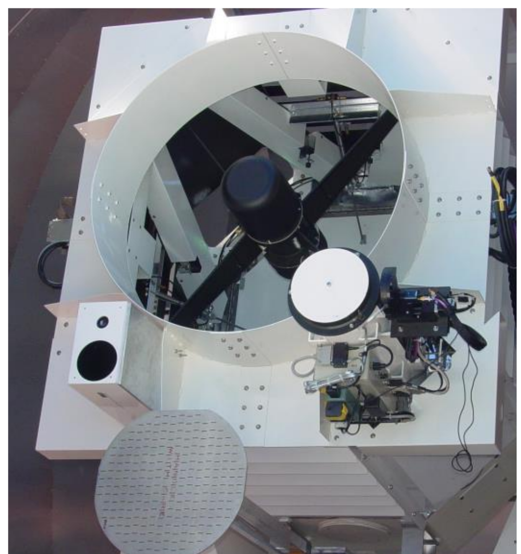
Generic Transceiver Block Diagram

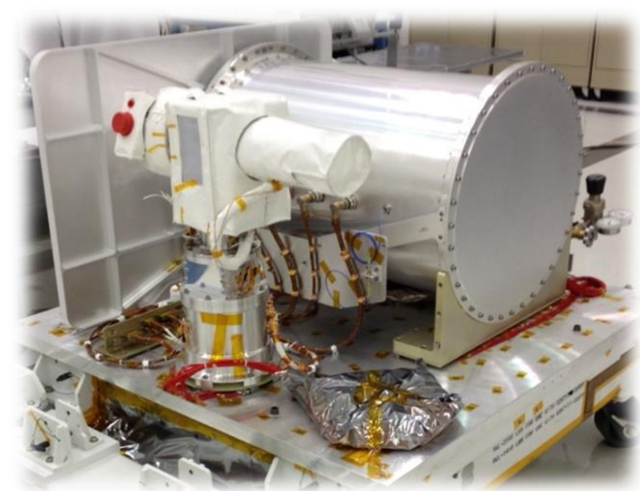




Ground Telescope



Flight Transceiver



LLCD & Lunar Lasercom OCTL Terminal (LLOT)

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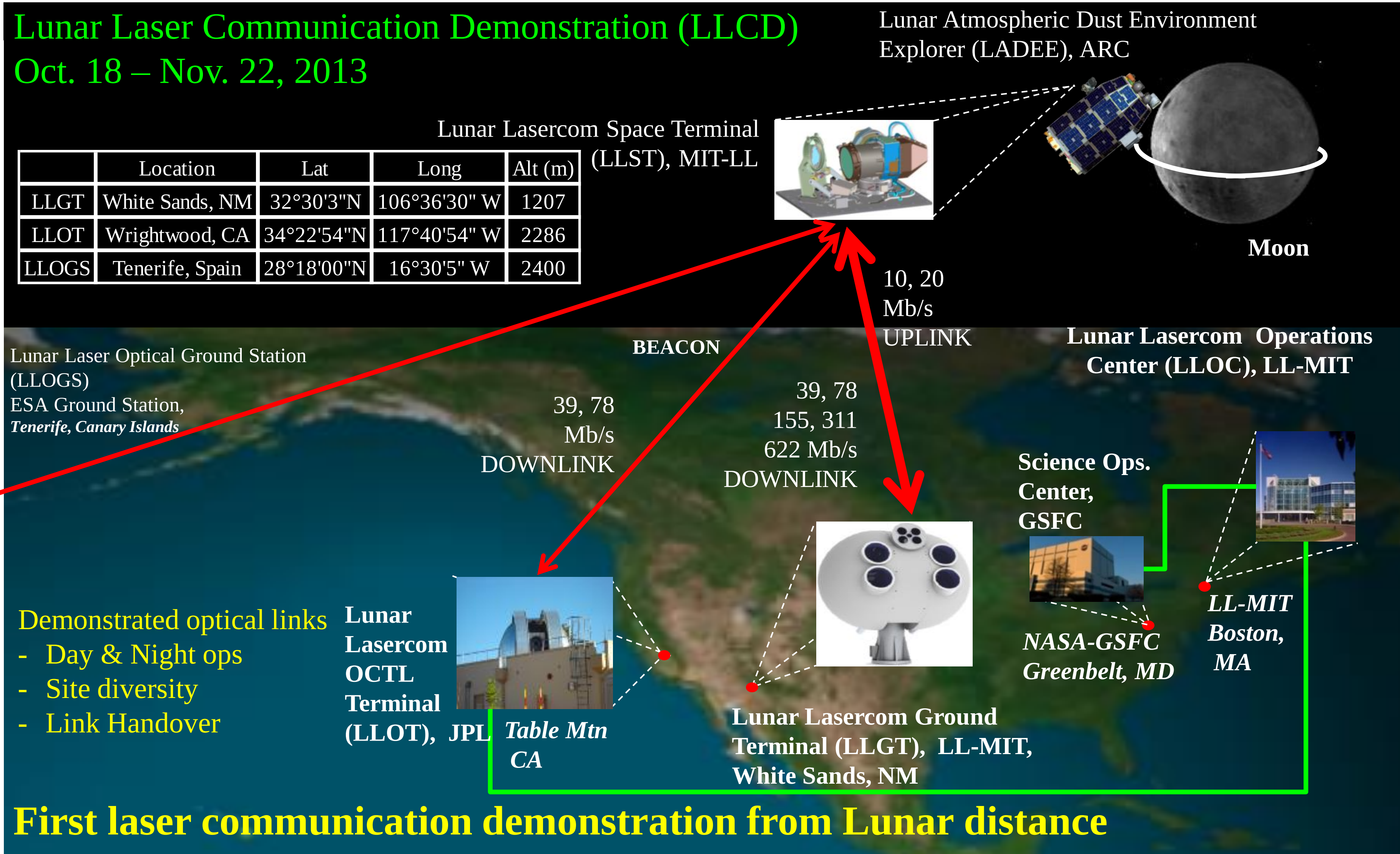
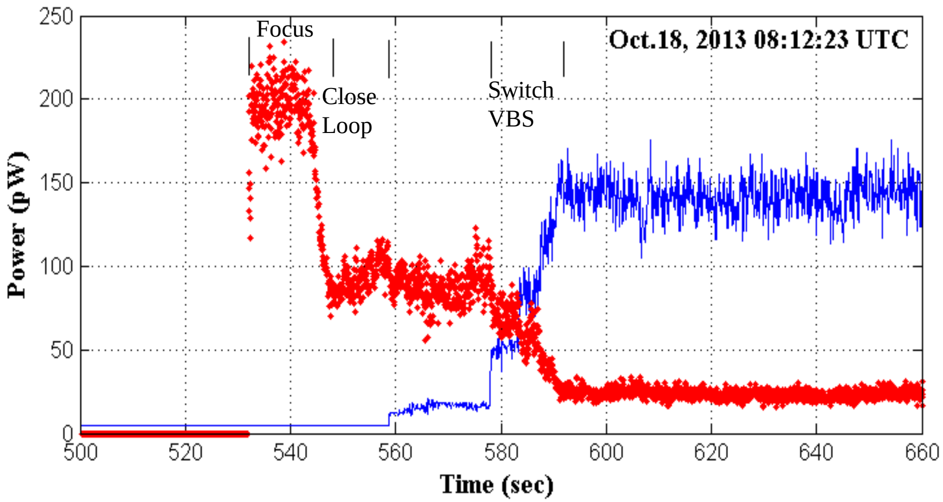
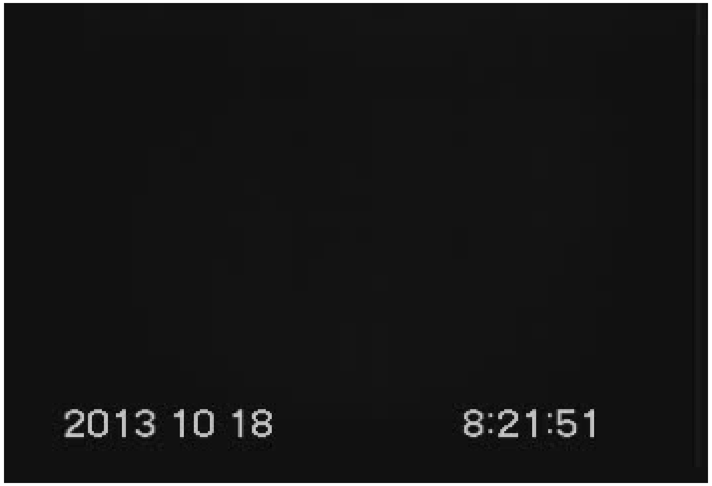


	Location	Lat	Long	Alt (m)
LLGT	White Sands, NM	32°30'3"N	106°36'30" W	1207
LLOT	Wrightwood, CA	34°22'54"N	117°40'54" W	2286
LLOGS	Tenerife, Spain	28°18'00"N	16°30'5" W	2400

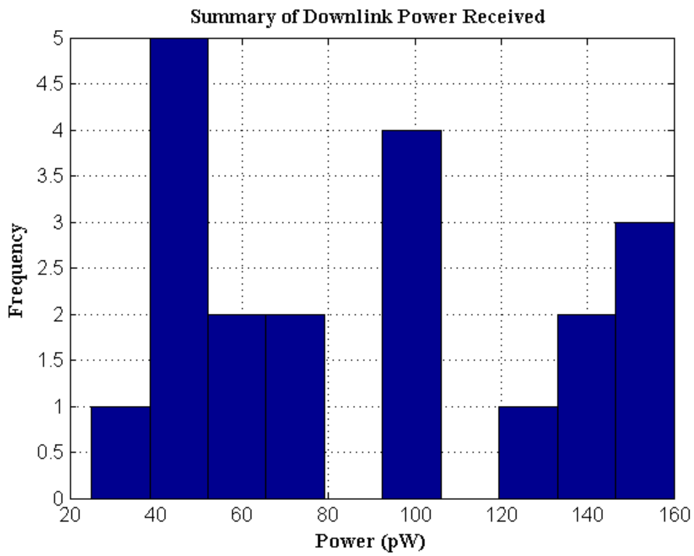
Downlink Acquisition

- **Downlink average power falls within the predicted bounds**
  - Link analysis
  - Current best estimates during testing of LLOT





	Nominal	Worst	Best
LLST EIRP transmiting 0.5 W (dBW)	99.1	99.1	99.1
LLST Pointing Loss (dB)	-0.6	-1.5	-0.4
Space Loss (dB)	-310.7	-310.9	-310.0
Atmospheric Loss (dB)	-0.5	-3.1	-0.3
Ground Net gain (dB)	114.4	113.4	115.4
Net Received Power (dBW)	-98.3	-102.9	-96.2
Power in pW	148.7	51.0	242.2



OVERVIEW Optical Payload for Lasercomm Science (OPALS)

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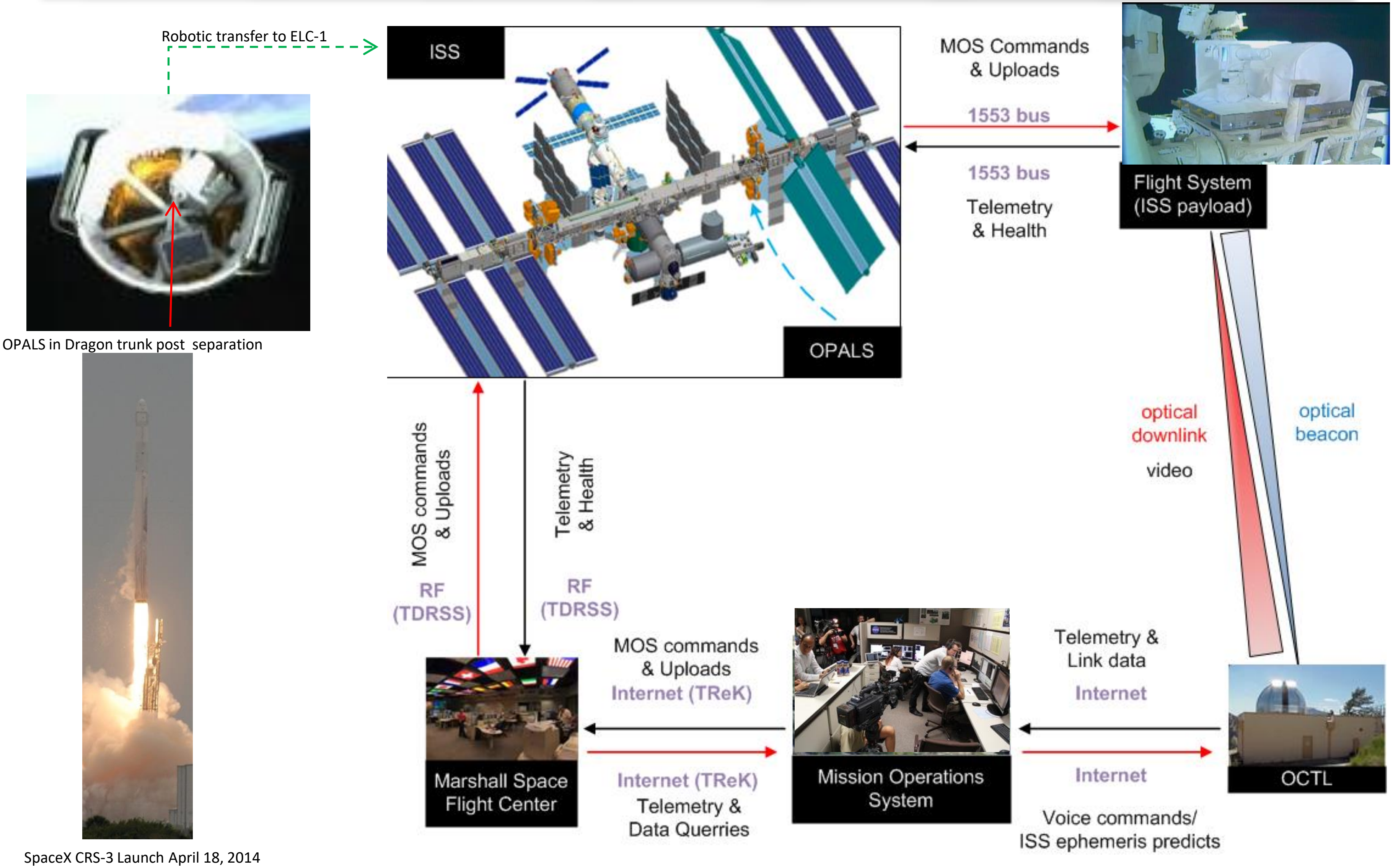
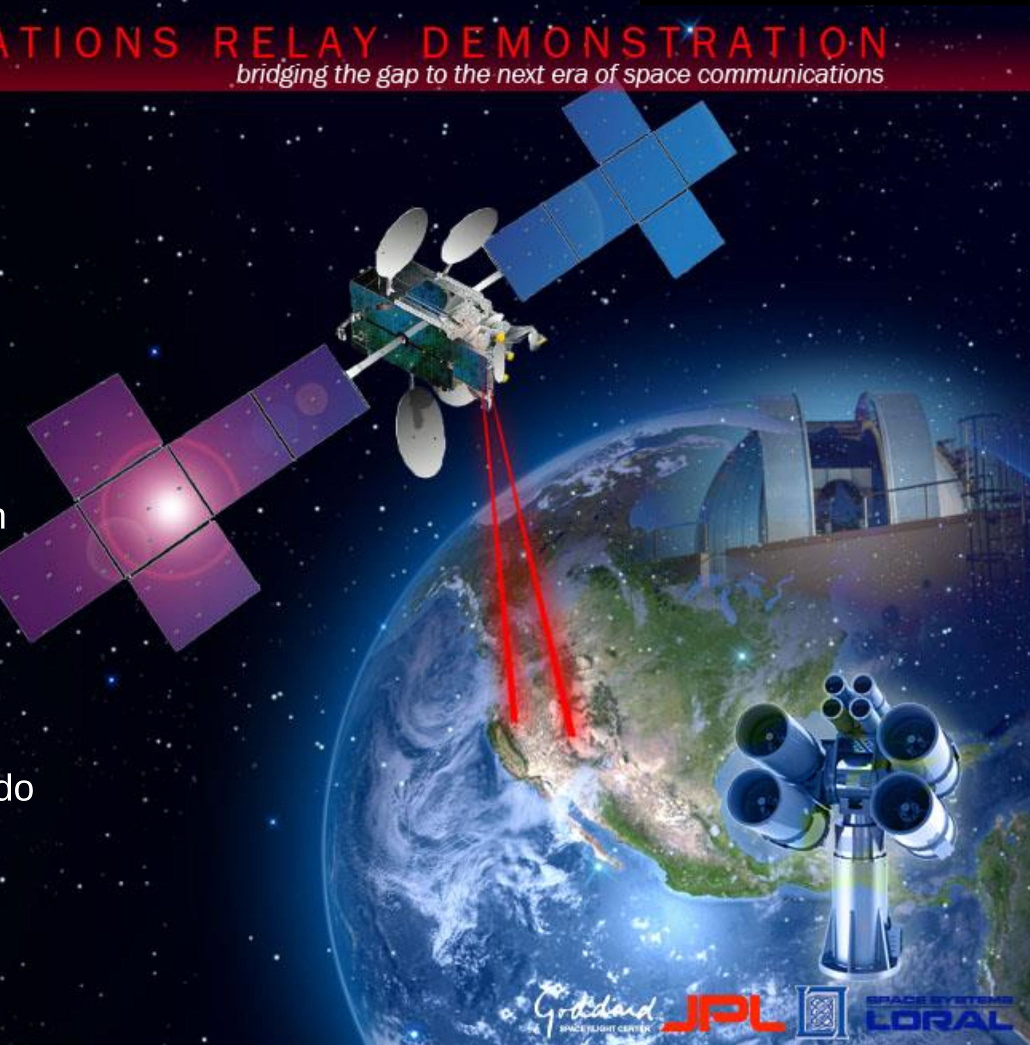


FUTURE SYSTEMS

Planned in 2019-2020



- Twin terminals on GEO platform
  - Data transmitted from OCTL at Table Mountain
  - Relayed to Ground Station at White Sands, NM
- JPL to deliver the ground station at OCTL
  - Key challenge is to implement an Adaptive Optics System
  - Based on wave-front sensor,
    - Less power than self-referencing interferometer
  - Lower bandwidth but GEO links do not have slew rates
  - Bi-directional DPSK @ 1.2 Gb/s
  - Downlink? PPM at 311 Mb/s

Pre-Decisional Information -- For Planning and Discussion Purposes Only

NASA Near-Earth Lasercom Development LEMNOS

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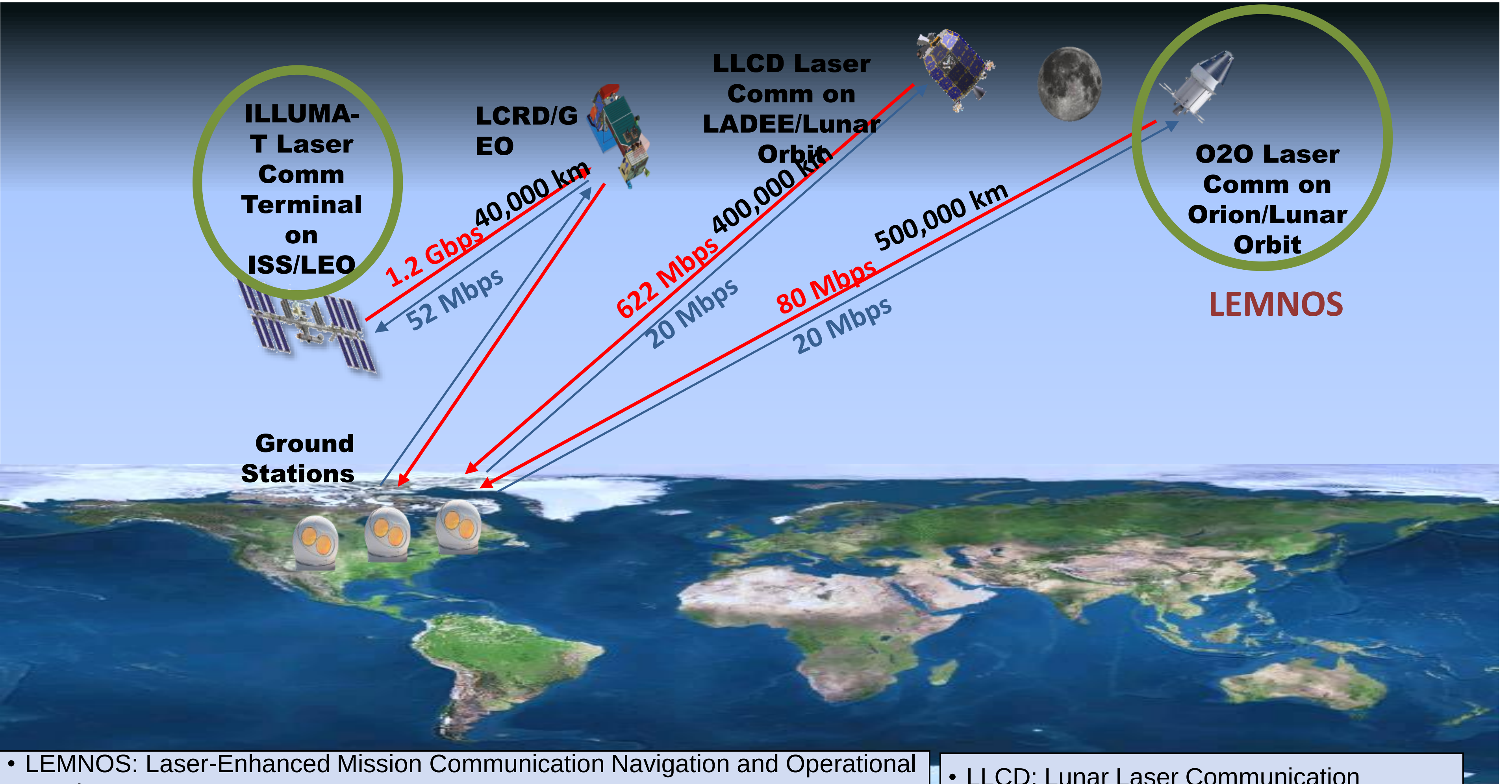
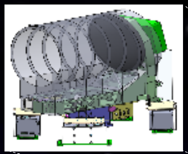


- LEMNOS: Laser-Enhanced Mission Communication Navigation and Operational Services
- ILLUMA-T: Integrated LCRD LEO (Low-Earth Orbit) User Modem and Amplifier Terminal
- O2O: Orion EM-2 Optical Comm

- LLCD: Lunar Laser Communication Demonstration
- LCRD: Laser Communication Relay Demonstration

Deep-Space Optical Communications (DSOC) Concept

Flight Laser Transceiver (FLT) 4W, 22 cm



Psyche Spacecraft (2022)

1064 nm uplink
1.6 kb/s < 1 AU

– ***OBJECTIVES:***

Advance NASA's enhanced communication goals by:

– *Demonstrate optical communications from deep space to validate:*
  – *Link acquisition/re-acquisition and laser pointing control*
  – *High photon efficiency signaling (implement emerging CCSDS standard)*

1550 nm downlink

Data-rate (Mb/s)	Distance (AU)
132	< 0.25
14	> 0.25 <1.0
2	> 1 < 2.0
0.2	> 2 <2.6

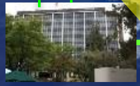
Ground Laser Transmitter (GLT)
Table Mtn., CA
1m-OCTL Telescope
(5 kW)

Ground Laser Receiver (GLR)
Palomar Mtn., CA
5m-dia. Hale Telescope

Deep Space Network (DSN)

Psyche Ops Center

DSOC Ops Ctr.



Pre-Decisional Information -- For Planning and Discussion Purposes Only

Summary

- **Advances in space laser communications over past two decades**
- **Future activities planned in next decade**
- **Maturing optical communications is compelling**
- **Technology development and conops will advance in the next two decades**